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The Effect of Socioeconomic Factors and Healthcare Access Indicators on COVID-19 Vaccination Rates Within U.S. Communities

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ABSTRACT

PURPOSE: This thesis aims to evaluate the influence of key indicators of healthcare access, socioeconomic factors, and population demographics on COVID-19 vaccination rates among U.S. counties. Moreover, this thesis also serves to examine COVID-19 vaccination rates across the rural-urban continuum. Additionally, we provide insights that illuminate the indicators and behaviors that may be strategically utilized to assist policymakers on COVID-19 vaccination and mitigation strategies.

METHODS: We use a three-pronged multivariate linear regression model to analyze the association of health-related factors with COVID-19 vaccination uptake at important phases during the COVID-19 vaccine distribution process. Time 1 signifies the initial phases of the COVID-19 vaccine distribution period when vaccines were moderately accessible; Time 2 signifies one month after the FDA approval of the first COVID-19 vaccine; and Time 3 signifies the end of the vaccination rollout period when the vaccine was widely available to most. To examine the leading research questions, we employ two prominent datasets: 1] the 2021 County Health Rankings & Roadmaps (CHR&R) national dataset from the University of Wisconsin Population Health Institute, and 2] the Centers for Disease Control and Prevention (CDC) national database for COVID-19 vaccinations at the county level.

RESULTS: The notable findings throughout all three time periods show statistically significant associations among uninsurance rates, the prevalence of primary care providers per 100,000 population, and the proportion of American Indian and Alaska Native individuals on COVID-19 vaccination coverage.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Chapter 1

Examining the Literature

Overview of COVID-19 in the United States

The coronavirus pandemic continues to impact the healthcare structures and economies of countries across the globe. The 2019 coronavirus, COVID-19, immensely challenged the American healthcare structure by dramatically fueling the need for life-saving healthcare services in a state of emergency coupled with limited supplies, equipment, and resources. The COVID-19 pandemic strained health systems in unprecedented ways, with several healthcare networks struggling to combat unforeseen limitations in staffing and medical personnel, supplies such as personal protective equipment (PPE), ventilators, medications, oxygen machines, vaccinations, and more. The pandemic put extreme stress on the healthcare workforce in the United States, leading to major workforce shortages and increased healthcare provider burnout, exhaustion, and trauma. During the height of the pandemic, surges in COVID-19 and its subsequent variants (the delta, omicron, or alpha variants) stressed hospital systems and public health infrastructures. [1] Resource limitations – including a limited number of hospital beds and capacity to treat patients, staffing issues, and insufficient supplies – led some facilities to adopt crisis standards of care, an extreme operating condition for healthcare organizations in which the decision-making process shifted from achieving superior health outcomes for patients to addressing the *immediate* care needs of patients. When hospitals diverged from conventional care during the peak of the pandemic, consequently, many elective and preventive procedures were postponed, enabling the progression of more severe conditions among patients that could have benefitted from earlier care; this served to further stress healthcare organizations by creating a backlog or influx of patients in need of healthcare services deemed non-essential or non-emergent. [2]

To mitigate the transmission of COVID-19, the Centers for Disease Control and Prevention (CDC) took extraordinary action throughout the duration of the pandemic to actively address the public health threat. The pandemic challenged many households and communities across the U.S. To examine how families managed throughout the unprecedented health crisis, the U.S. Census Bureau utilized the Household Pulse Survey to collect relevant data from 2020 to 2021. [3] The survey aimed to produce more data on the social and economic effects of the coronavirus and other key issues. The Pulse surveys revealed that hardship would have increased in 2020 and 2021 without significant aid from the federal government, states, and local entities; substantial relief measures from government entities directly contributed to a reduction in hardship indicators such as unemployment, food scarcity, and housing issues due to financial instability.[4] However, even with assistance, the Pulse survey found that in October 2021, nearly 20 million U.S. adults lived in food-insecure households and 12 million adult renters were behind on rent. [5] It is evident that despite relief efforts, the pandemic presented significant challenges and disruptions to daily life.

When COVID-19 vaccines were limited in supply but authorized for emergency use, the CDC began COVID-19 vaccination allocation through phases starting with healthcare personnel and residents of long-term care facilities in December 2020. [6] The U.S. Federal Drug Administration (FDA) officially approved the first COVID vaccine, the Pfizer-BioNTech COVID-

19 vaccine, in August 2021 for individuals 16 years of age and older. [7] Since then, the COVID-19 vaccine was distributed throughout communities and became widely available to most people.

Health and Wellness During the Pandemic

Health is influenced by factors that filter into five broad categories as the determinants of health: genetics, behavior, environmental and physical influences, medical care, and social factors. [8] The social determinants of health (SDOH) include the interconnected non-medical factors that influence health outcomes. [9] They are the conditions in which people are born, grow, live, and work that comprise a wider set of forces and systems that collectively contribute to daily life. [10]

Socioeconomic disparities and health inequities existed in the United States far before the onset of COVID-19. The CDC defines health disparities as “preventable differences in the burden of disease, injury, violence, or opportunities to achieve optimal health that are experienced by populations that have been disadvantaged by their social or economic status, geographic location, and environment.” [11] Previous research indicates that certain racial and ethnic minorities experience disparities in the burden of disease and illness. Some minority groups experience higher rates of poor health and disease for various medical conditions such as hypertension (commonly known as high blood pressure), diabetes, asthma, cancer, heart disease, preterm birth, and obesity, compared to their White counterparts. [12] For example, the CDC reports that the average life expectancy for Black people is four years lower than that of White people.

The pandemic created a time of crisis that exacerbated pre-existing health disparities among marginalized or minority groups, fueled by limited resources and fearful people. Individuals of certain groups including low-income earners, people without health insurance, those with preexisting health conditions, people of color, and ethnic or racial minorities were disproportionately impacted by COVID-19. [13] A recent systematic review aimed to examine published evidence (from December 2019 through March 2021) on the association of racial or ethnic and socioeconomic status with health outcomes and indicators of healthcare accessibility during the pandemic. [14] Relative to socioeconomic disparities, 28 studies examined the association between COVID-19 health outcomes and socioeconomic characteristics. The studies cohesively reflected that living in poverty or economic instability, employment in the healthcare sector and social assistance transportation services, household overcrowding, lack of health insurance, lower household income, and limited educational attainment were all associated with an increased risk of contracting COVID-19. One study by Maness et al. examined social disparities relative to COVID exposure and mortality prevalence among African American people. Maness et al. find that compared with non-Hispanic White people, "African American people have higher rates of COVID cases (2.6 times higher), hospitalization (4.7 times higher), and death (2.1 times higher)." [15] This disproportionate mortality rate is indicative of a long history of health inequities that require widespread changes to eliminate systemic racism and improve disparities relative to the socioeconomic determinants of health.

Healthcare in Rural America During the Pandemic

Approximately 60 million persons in the United States live in rural counties, representing about one-fifth (19.3%) of the population. [16] A large portion of the population, about 1 in 5 people, live in rural areas. Figure 1 depicts the CDC's National Center for Health Statistics (NCHS) urban-rural classification scheme. [17] The overwhelming majority of Figure 1 is green, representing a large proportion of micropolitan and rural areas.

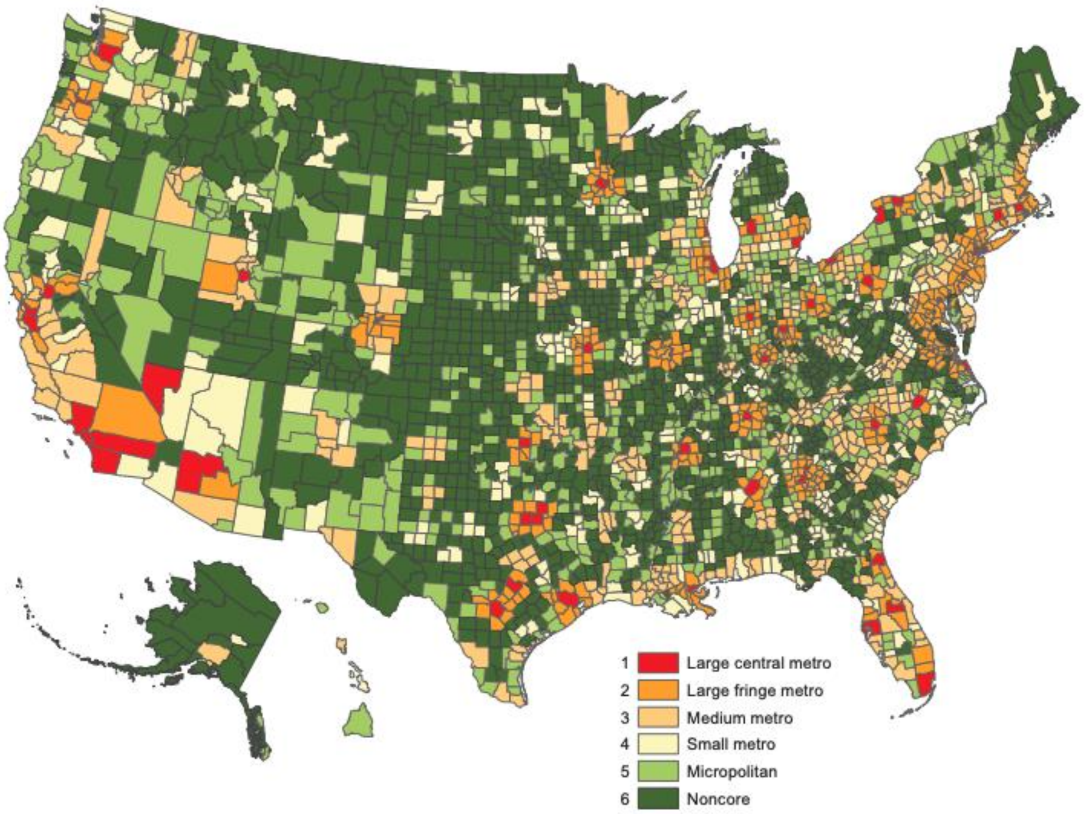


Figure 1. Distribution of counties according to the 2013 NCHS Urban-Rural Classification Scheme for Counties [18]

In a recent study, researchers sought to examine whether the adoption of COVID-19-related health behaviors varied in rural versus urban communities of the U.S. while considering the influence of political ideology, experiences of COVID-19, and demographic factors. [19] To do so, the researchers relied on a representative survey collected from May to June 2020. Upon analyzing the survey responses, results showed that rural residents were significantly less likely to have worn a mask in public, sanitized their home or workplace with disinfectant, worked from home, or avoided dining at restaurants or bars. These findings stipulate that rural residents were less likely to participate in several COVID-19 mitigation efforts and prevention behavior compared to their urban counterparts. [20]

The vulnerabilities of rural areas, including barriers to healthcare accessibility, the ability to seek and obtain quality healthcare services, and poor health, increased due to the pandemic. Rural communities often have a higher proportion of residents who lack health insurance, are aged 65 and older, live with comorbidities or disabilities, and have limited access to healthcare facilities and intensive care capabilities. [21] As it follows, since late 2020, research indicates that the cumulative COVID-19 mortality rate has been higher in rural counties compared to urban counties of the U.S. [22]

A recent study examined the variation in COVID-19 vaccination coverage across the rural-urban continuum, using CDC on vaccination rates among U.S. adults from 2,869 counties. The findings showed that as of August 2021, 48.5% of adults in rural counties had been fully vaccinated, compared to 59.8% in urban counties. [23] Rural residents report lower COVID-19 vaccination rates due to several potential explanations. First, vaccination hesitancy has been identified as principal contributors to lower rural vaccination coverage in rural areas. [24] Second, the availability of COVID-19 vaccines did not always translate to accessibility. [25] Counties with more vulnerable populations — larger shares of racial or ethnic minorities, higher rates of poverty, and increased uninsurance rates — have been found to have lower vaccination rates. [26] Vaccine hesitancy and resistance have been identified as principal contributors to lower rural vaccination coverage. The Kaiser Family Foundation (KFF) COVID-19 Vaccine Monitor is an ongoing research project that aims to assess the public's attitudes, beliefs, and experiences with COVID vaccination. The KFF findings from December 2020 indicated that:

Rural residents are among the most vaccine hesitant groups, along with Republicans, individuals 30-49 years old, and Black adults. Individuals living in rural areas in the U.S. are significantly less likely to say that they will get a COVID-19 vaccine that is deemed safe and available for free than individuals living in suburban and urban America. Three in ten (31%) people in rural areas say they will "definitely get" the vaccine, compared to four in ten people in urban areas (42%) and suburban areas (43%). An additional one-third of people in rural areas say they will "probably get it" while 35% say they will either "probably not get it" (15%) or "definitely not get it" (20%). [27]

Rural areas experience lower COVID-19 vaccination rates compared to urban areas. Figure 2 depicts responses to the question, "If a COVID-19 vaccine was determined to be safe by scientists and was available for free to everyone who wanted it, would you...?"

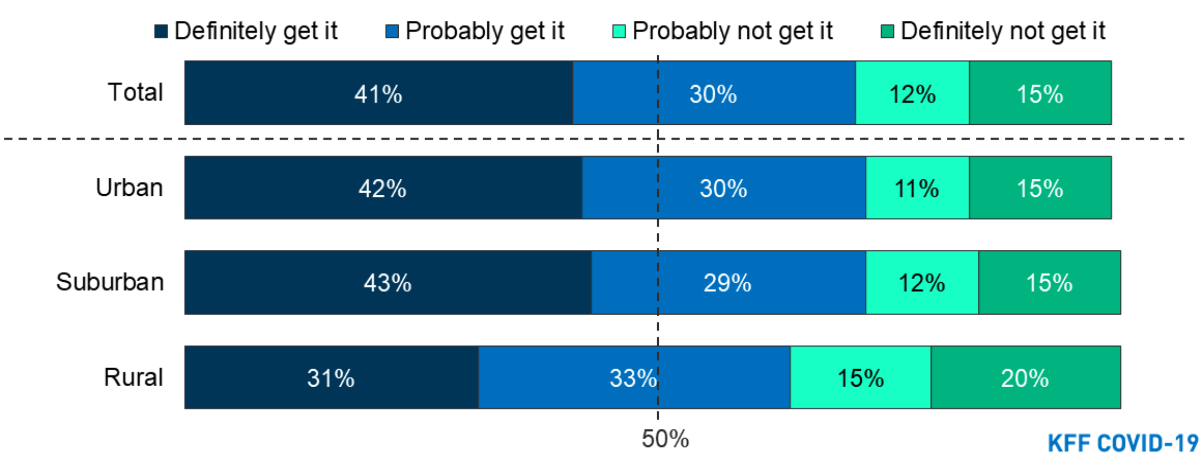


Figure 2: Smaller shares of rural residents say they will "definitely get" a COVID-19 vaccine [28]

The KFF survey results identify rural residents to have the smallest proportion of individuals that will "definitely get" a COVID-19 vaccine. [29] Vaccination hesitancy is linked to rural conceptions about COVID-19 that downplay the seriousness of the virus. [30] The KFF survey results indicate that four in ten rural residents (39%) say they are *not* worried they or someone in their family will get sick from the coronavirus, as compared to 23% of urban residents and three in ten suburban residents (30%).[31] The variance between rural and urban residents' perceptions of COVID-19 is reflected in Figure 3.

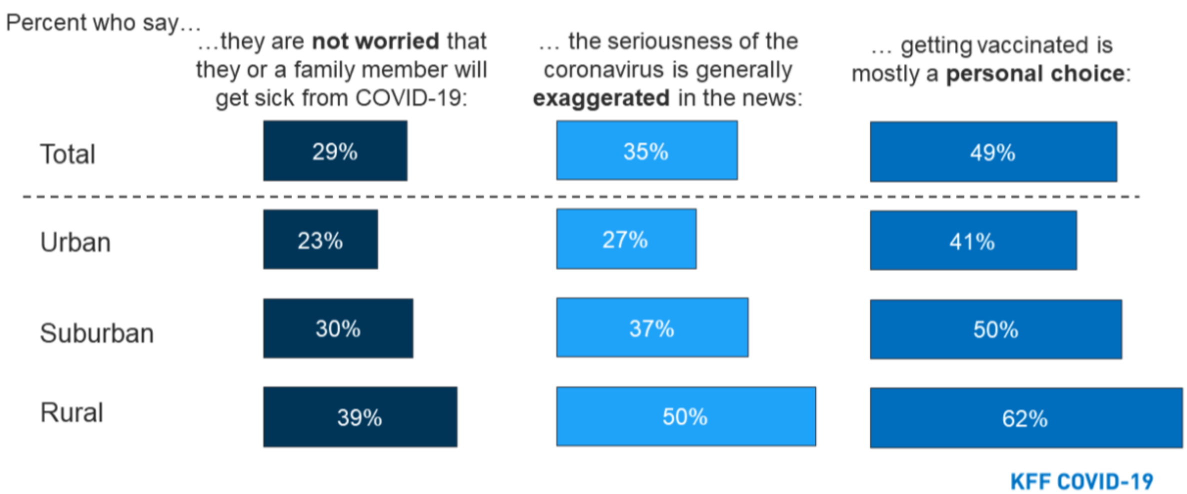


Figure 3. Fewer Rural Residents Are Worried About Getting Sick [32]

COVID-19 & Healthcare Access

Maintaining adequate levels of healthcare access among U.S. residents was a challenge prior to the pandemic. While minor complications can be treated at home, severe sickness from COVID-19 often requires hospitalization or advanced medical care. The influx of patients seeking healthcare services for COVID-19 greatly increased inpatient healthcare utilization and caused limited resources to be allocated to treat COVID-19 patients and reduce patient suffering. [33] While overall healthcare utilization has increased since the pandemic, individuals in high-risk groups (such as older adults and minority groups) report barriers to access. [34] To elaborate, the States implementation of stay-at-home orders may have led to increased cancellations of scheduled medical appointments. Fear of contracting COVID-19 may have also caused patients to neglect or push off seeking healthcare services. One recent study examined healthcare access during the pandemic for Medicare beneficiaries 65 years or older. This study utilized a cross-sectional survey approach to survey respondents in the summer (June to July) and fall (October to November) of 2020. The summer survey results indicated that 20.9% of respondents (n=8751) indicated that they were unable to access healthcare due to the COVID-19 pandemic. [35] As the prevalence of COVID was high summer of 2020, fall survey results found that fewer respondents (7.5%) reported that they were unable to access healthcare due to the pandemic. [36] Moreover, the study's findings indicated that "beneficiaries with multiple chronic conditions who are known to use health care services frequently experienced higher rates of inability to access health care due to the pandemic than their counterparts." [37] While access to healthcare varied, it is evident that individuals experienced hardship accessing care due to the pandemic.

COVID-19 Vaccination

As of February 1, 2023, 81% of the total population has had at least one dose, and 69.2% of the total population completed the primary series. [38] While most residents have received at least one dose, this also means that 19% of the population remains completely unvaccinated for COVID-

19. To reduce the transmission of the coronavirus, public health efforts should continue to strive toward increased vaccination prevalence and reaching herd immunity. Herd immunity occurs when a large enough portion of the population has developed antibodies (either from overcoming disease or getting vaccinated) that reduce person-to-person transmission and protect those who are unable to be vaccinated, such as cancer patients, the immunocompromised, and the very young or very old. [39]

Relevant research unanimously reports that higher levels of vaccination coverage is associated with lower COVID-19-related mortality and incidence in the United States. [40] In March 2022, researchers Suthar et al. conducted an observational study of the population utilizing county-level surveillance data on COVID-19 cases, deaths, and vaccinations reported to the CDC. [41] The researchers analyzed 30,643,878 cases of COVID-19 and 439,682 COVID-19-related deaths across 2558 counties. From December 2021 to 2022, the first year of the distribution of the COVID-19 vaccines, the study results indicated that every 10% improvement in vaccination coverage was associated with an 8% reduction in mortality rates and a 7% reduction in case incidence. [42] Suthar et al. measured COVID-19 reported incidence and mortality in counties with very low (0-9%), low (10-39%), medium (40-69%), and high (greater than 70%) vaccination coverage among adults. [43] During the first half of 2021, the COVID-19-related mortality rate was "reduced by 60%, 75%, and 81% in counties with low, medium, and high vaccination coverage, compared with counties that had very low coverage. The corresponding figures for the reduction in case incidence were 57%, 70%, and 80%." [44] It is evident that achieving widespread COVID-19 vaccination coverage is vital to reduce unnecessary death and suffering caused by the virus.

Unfortunately, structural and attitudinal barriers interfere with COVID-19 vaccination uptake. Structural barriers include systemic issues that limit a person's access to receiving the vaccine. Relevant research identified key structural barriers to vaccination that include: cost including the price of the vaccine, medical service, and all other costs incurred; convenience including the time someone must take to get vaccinated, physical access, and geographic proximity to a vaccination site; and supply chain issues that cause disruptions or constraints to the production and dissemination of vaccines (Table 1). [45] Alternatively, attitudinal barriers include the beliefs or perceptions that reduce one's willingness to seek and accept vaccination services**.** To examine these barriers, public health initiatives should strive to work alongside communities to build partnerships, listen to concerns, combat misinformation, and provide education to allow individuals to make informed decisions. [46] Prevalent attitudinal barriers to vaccination include a low perceived risk of contracting the virus, the belief that the COVID-19 vaccine is harmful, a lack of trust or suspicion of medical institutions, misinformation regarding the vaccine, and overall misconceptions rooted in a lack of knowledge about COVID-19 (Table 2). [47]

Barrier	**Description**
Cost	The price of the vaccine or medical visit to receive the vaccine that is incurred by the individual.
Convenience	The time someone must take to get vaccinated included the ease of transportation and geographic and functional proximity to a vaccination site.

Supply chain issues	The disruptions to or constraints on the production, distribution, and delivery of the vaccines which was particularly challenging throughout the pandemic.

Table 1. Common structural barriers to vaccination uptake in the U.S. [48]

Barrier	**Description**
Complacency in illness prevention	A low perceived risk of contracting the illness and underestimating the severity of the disease itself.
Perceived risks of vaccines	The belief that vaccines are harmful (ie. cause the disease they claim to prevent, lead to autism, ext.)
Lack of trust	Medical mistrust towards vaccines, regulatory or federal agencies that monitor vaccine development and distribution, healthcare workers who deliver vaccines, and the companies that manufacture the vaccines.
Misinformation	False information about vaccines that is created and distributed.
Misconceptions	A lack of knowledge and understanding about vaccines and their level of effectiveness and safety.

Table 2. Common attitudinal barriers to vaccination uptake in the U.S. [49]

The task to increase COVID-19 vaccination coverage is challenged by several barriers, many of which relate to the social determinants of health, socioeconomic factors, indicators of healthcare access, and healthcare disparities among disadvantaged populations. Similar to the disparities observed in disproportionate rates of COVID-19 prevalence and mortality within disadvantaged populations, disparities in vaccination uptake exist across vulnerable populations and communities.

The Gap in the Literature

Since the onset of COVID-19, substantial research and technological advancement propelled the country toward a healthier future through vaccination uptake and other strategic mitigation efforts. The influences on COVID-19 vaccination uptake and barriers to reaching high vaccination rates are well documented in the literature. For instance, it is widely accepted that individuals of color faced disproportionate disadvantages relative to COVID, and ultimately reflected poor outcomes and higher mortality rates. While the influences of COVID-19 vaccination uptake are documented, there exists a gap in knowledge on the association of key socioeconomic, demographic, and healthcare access indicators on COVID-19 vaccination coverage among U.S. counties. Moreover, this thesis serves to provide a unique perspective by accounting for major events in the COVID-19 vaccination rollout and distribution period in the United States.

Chapter Two

The Effect of Socioeconomic Factors and Health Access Indicators on COVID-19 Vaccination Rates within U.S. Communities

Background and Research Questions

Achieving high levels of COVID-19 vaccination coverage across communities in the United States is critical to minimize the negative implications of the ongoing pandemic. An effective vaccine helps protect both the recipient and those around them from severe illness, hospitalization, and even death; it also reduces person-to-person transmission within communities. Since the onset of the pandemic, many communities have experienced low vaccination rates. Moreover, socioeconomic factors (i.e. education and income) and indicators of healthcare access (e.g. the number of primary care providers within a county) potentially influence the uptake of COVID-19 vaccines. This thesis seeks to examine the association of socioeconomic factors and indicators of healthcare access with COVID-19 vaccination rates across U.S. counties. Specifically, we try to answer the following primary research questions:

RQ1] How do key indicators of healthcare access influence COVID-19 vaccination coverage among U.S. counties?

RQ2] How do central socioeconomic factors influence COVID-19 vaccination coverage among U.S. counties?

RQ3] How does the rural-urban continuum across U.S. counties influence COVID-19 vaccination rates?

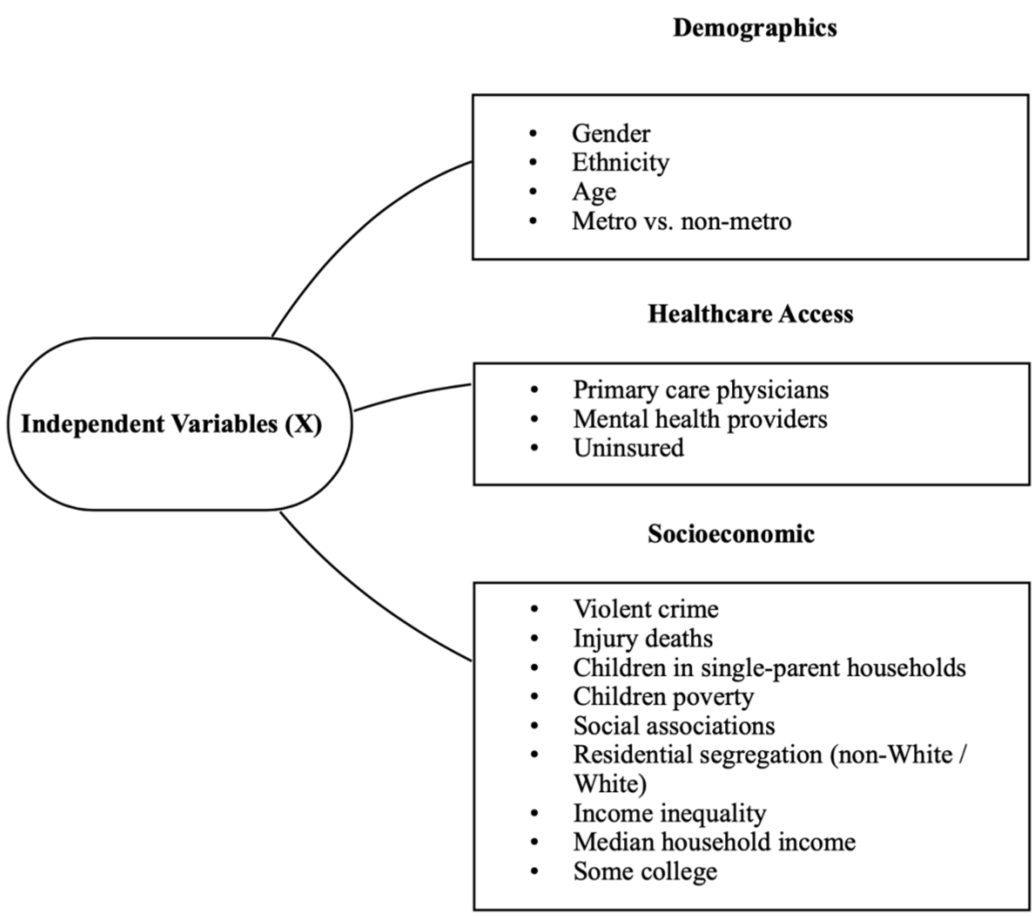
The first research question (RQ1) examines the association between COVID-19 vaccination coverage and indicators of healthcare access among U.S. counties. Specifically, RQ1 examines the following indicators of healthcare access: access to healthcare services as measured by the prevalence of primary care physicians and mental health providers per 100,000 population;

health insurance coverage and the uninsured; and the geographic rural-urban continuum. The second research question (RQ2) examines the association between COVID-19 vaccination coverage and socioeconomic factors across counties. RQ2 analyzes the association among COVID-19 vaccination prevalence and principal socioeconomic factors that influence health including: the rate of violent crimes and injury-related deaths; the percentage of children living in households headed by a single-parent; engagement in social associations and memberships; economic indicators including median household income, income inequality, and poverty; levels of educational attainment; residential segregation as a determinant of racial differences in socioeconomic mobility; and demographic factors including race, age, and gender. The third research question (RQ3) examines the influence of rurality and urbanicity on COVID-19 vaccination rates. Specifically, RQ3 examines if rural areas report disproportionate COVID-19 vaccination rates as compared to urban areas. RQ3 investigates how living in rural or urban areas is associated with COVID-19 uptake.

To examine the association between county-level indicators of healthcare access, socioeconomic status, and demographic factors with COVID-19 vaccination coverage, the researcher strategically implores a three-pronged multivariate regression analysis. The regression model examines the association among various independent variables (X) on the outcome variable — COVID-19 vaccination completion rates (Y).

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + \in$$

X_X : independent variables of healthcare access, socioeconomic factors, and demographics
Y : the outcome variable, COVID-19 vaccination coverage
b_X : regression coefficients
$\in$: random error



** For more details on variables refer to Appendix A.**

In this model, the dependent variable (Y) is the percentage of people who have successfully completed a primary COVID-19 vaccination series. As sourced from the CDC's COVID-19 vaccination dataset, the outcome variable is the percentage of individuals who have received a second dose of a two-dose vaccine, or one dose of a single-dose vaccine based on the county and jurisdiction in which they live. [50] The regression model in this analysis measures the same independent variables with COVID-19 vaccination coverage as the outcome variable on three different dates (Time 1, Time 2, & Time 3). Specifically, the regression model examines the association of key variables as reflected in Table 3 on COVID-19 vaccination coverage among U.S. counties.

Variable Name	Brief Description
Female	The percent of the population that is biologically female.
Hispanic	The percent of the population that is Hispanic alone.
Asian	The percent of the population that is Asian alone.
American Indian & Alaska Native	The percent of the population that is American Indian and Alaska Native alone.
Non-Hispanic Black	The percent of the population that is Black or African American alone.
Below 18 years of age	The percentage of the population that is less than 18 years of age.
Metro vs. nonmetro	The prevalence of counties with a population of less than 50,000 people.
Primary care physicians	The number of primary care physicians per 100,000 county residents.
Mental health providers	The number of mental health providers per 100,000 county residents.
Uninsured	The percentage of the population under age 65 without health insurance.
Violent crime	The number of reported violent crime offenses per 100,000 population.

Injury deaths	The number of reported injury deaths per 100,000 population.
Children in single-parent households	The total percentage of children that live in a household headed by a single parent.
Children in poverty	The percentage of the population that is less than 18 years of age and living in poverty.
Social associations	The number of membership associations per 10,000 population.
Residential segregation White/non-White	An index of dissimilarity where higher values indicate greater residential segregation between non-White to White county residents.
Income inequality	The ratio of household income at the 80th percentile to that at the 20th percentile.
Median household income	The income at which half of the households in a county earn more and half earn less.
Unemployment	The percentage of the population 16 and up that is unemployed but seeking work.
Some college	The percentage of adults aged 25 to 44 with some post-secondary education.

Table 3. Explanatory variable names and brief description

We use multivariate linear regression models to analyze the association of health-related factors with COVID-19 vaccination uptake at three important phases during the COVID-19 vaccine rollout period. Specifically, we investigate COVID-19 vaccination prevalence on three dates: April 8, 2021 (Time 1), which marks sometime after vaccines first became available for certain individuals (i.e. healthcare workers and essential workers, those aged 75 and older living in a long-term care facility); September 29, 2021 (Time 2), which captures sometime after the

FDA approved the first COVID-19 vaccine in late August; and June 10, 2022 (Time 3), which marks a point in which the COVID-19 vaccine was widely available for most individuals.

When the COVID-19 vaccine supply was limited, the Federal Advisory Committee on Immunization Practices (ACIP) advised that the vaccine should be distributed in phases. [51] On December 18, 2020, the U.S. Food and Drug Administration (FDA) issued an emergency use authorization (EUA) for the Moderna COVID-19 vaccine. [52] An emergency use authorization (EUA) is a tool the FDA used to expedite the availability of the vaccine during an unprecedented pandemic, however, it does not signify official FDA approval of the vaccine. On December 22, 2020, the ACIP and the CDC published a model for equitable vaccine distribution: phase 1a includes healthcare personnel and residents of long-term care facilities; phase 2b includes essential workers and all persons ages 75 years and older; phase 1c includes all person's ages 65 to 75, and all persons ages 16 to 64 with a medical condition that increases their risk of severe disease from COVID-19; phase 2 includes all persons ages 16 years and older not already recommended in phase 1. [53] By late December 2020, more than one million vaccine doses were administered in the U.S. among healthcare workers and older adults living in long-term care facilities. [54] In early April 2021, the CDC estimated that "nearly 80% of pre-k-12 teachers, school staff, and childcare workers in the U.S. have received at least their first shot of the COVID-19 vaccine." [55] To examine the association of key indicators on COVID-19 vaccination, we utilize Time 1 (April 8, 2021) to signify a period when vaccines were moderately available for certain individuals across the country. On August 23, 2021, the FDA fully approved the first COVID-19 vaccine, the Pfizer-BioNTech vaccine, for all people ages 16 years and older. The FDA's approval of the first COVID-19 vaccine signified that this vaccine successfully met rigorous scientific standards and is both safe and effective. We utilize Time 2 (September 29, 2021) to capture COVID-19 vaccination rates one month after the FDA approval of the first COVID-19 vaccine. On June 17, 2022, the FDA expanded eligibility for the Pfizer-BioNTech and Moderna COVID-19 vaccines for children between the ages of 6 months and 5 years. [56] This marked the last major phase of the COVID-19 vaccination distribution process when vaccines became available to virtually all people in the United States. We utilize Time 3 (June 10, 2022) to signify a period in which the COVID-19 vaccine was generally available to most people.

Time	**Date**	**Significance**
Time 1	04/08/2021	The initial stages of the COVID-19 vaccine rollout. In this period, vaccines were available for certain individuals and supplies were limited.
Time 2	09/29/2021	One month after the FDA approved the first COVID-19 vaccine for individuals aged 16 years and older. In this period, vaccines were also available through EUA for individuals between the ages of 12 and 15. Therefore, the vaccine was available for individuals aged 12 and up.
Time 3	06/10/2022	The final stages of the COVID-19 vaccine rollout. In this period, vaccines and boosters were available to most people.

Table 4. Significant phases of COVID-19 vaccination rollout in the U.S.

Data Sources

To examine the leading research questions, we employ two prominent datasets: 1] the 2021 County Health Rankings & Roadmaps (CHR&R) national dataset from the University of

Wisconsin Population Health Institute, and 2] the Centers for Disease Control and Prevention (CDC) national database for COVID-19 vaccinations at the county level. The County Health Rankings & Roadmaps (CHR&R) is a program supported by the Robert Wood Johnson Foundation which aims to advance health and well-being by providing data, evidence, and guidance on factors that influence health and generate evidence-informed policies. [57] The CHR&R dataset is comprehensive and measures the health of nearly all counties across 50 States. We use the CHR&R dataset for all measures of healthcare access, population demographics, and socioeconomic factors (Appendix A). [58] Alternatively, we utilize the CDC COVID-19 vaccination database to longitudinally measure COVID-19 vaccination coverage over time from January 12, 2021, to June 10, 2022. [59] We solely use the CDC's COVID-19 vaccination dataset to measure population-level COVID-19 vaccination rates across counties (Appendix A). For statistical analysis, we examine the proportion of individuals fully vaccinated for COVID-19 and define "fully vaccinated" as the percent of people who have completed a primary series dosage (they have received a second dose of a two-dose vaccine or one dose of a single-dose vaccine) based on the jurisdiction and county where the vaccine recipient lives. [60]

Generation of The Study Sample

We conducted statistical analysis utilizing the Stata statistical software version 17 (Stata 17). As both datasets included county-level measures, we horizontally merged the datasets with the Federal Information Processing Standard (FIPS) codes serving as a unique identifier. FIPS codes uniquely identify all U.S. counties and county equivalents. As this analysis centers on data at the county and state level, we excluded American territories including Guam, Puerto Rico, and the Virgin Islands. According to the 2020 U.S. Census, there are 3,142 total counties and county-equivalents in the 50 states and the District of Columbia of the United States. [61] The dataset used for this analysis is comprehensive and includes all 3,142 counties (n= 3,142). Therefore, a variable with zero missing values would have 3,142 total observations representing all U.S. counties and county equivalents. To minimize the risk of missing variables diluting the validity of the results, we exclude measures with total observations of less than 2,500 as they do not capture comprehensive findings across counties.

Results

Overview

Throughout all three time periods, the results show a statistically significant association among uninsurance rates, the prevalence of primary care providers per 100,000 population, and the proportion of American Indian and Alaska Native individuals on COVID-19 vaccination coverage. Health insurance coverage contributes to positive health outcomes, connects patients with a regular source of care, and aids in the detection and management of illnesses and diseases. For this analysis as an indicator of healthcare access, uninsurance rates measure the percentage of the population under age 65 living without health insurance. The findings indicate that an increase in uninsurance was consistently associated with a decrease in COVID-19 vaccination coverage. Populations without health insurance coverage experience less access to healthcare and therefore, may be less likely to engage in healthy behaviors including vaccination uptake. Uninsured groups typically experience less engagement with the healthcare system and fewer interactions with providers as compared to the insured. Healthcare providers during regular check-up appointments might offer the COVID-19 vaccine to previously unvaccinated patients, advocate for vaccination uptake, and provide COVID-19-related information to patients. Individuals with health insurance may engage in these types of patient-to-provider interactions more frequently than those without. As another measure of healthcare access, we examine how the prevalence of primary care providers per 100,000 population influences COVID-19 vaccination rates. Results indicate that an increase in the number of primary care providers per 100,000 population was consistently associated with an increase in COVID-19 vaccination coverage. Populations with an increased number of primary care providers (PCPs) may report increased COVID-19 vaccination coverage as PCPs serve as the entry into the healthcare system, provide preventive healthcare services, and advocate for vaccination uptake. Moreover, the results indicate that an increase in the percentage of American Indian and Alaska Native individuals was associated with an increase in COVID-19 vaccination coverage throughout all three time periods. We hypothesize that perhaps this association reflects COVID-19 vaccination initiatives that focus on improving vaccination coverage within minority or disadvantaged populations. Moreover, we also hypothesize that the association between minority populations on COVID-19 vaccine coverage might stem from community-based structures that encourage healthy behaviors.

The time periods, Time 1, 2, and 3, chronologically signify phases throughout the COVID-19 vaccination distribution period. We observed a gradual increase in the number of significant associations throughout Time 1 (04/08/202), Time 2 (09/29/2021), and Time 3 (06/10/2022). Time 3 features the highest number of significant associations, while Time 1 features the least. The increase in statistically significant associations over time corresponds with the availability of the COVID-19 vaccine and the gradual spread of vaccination coverage.

Table 5. Regression Results Time 1, Time 2, & Time 3

		Time 1 (Beta)	Time 2 (Beta)	Time 3 (Beta)
Gender				
	Female	0.062	0.745***	0.400**
Race				
	Asian	0.164	0.483***	0.169
	American Indian & Alaska Native	0.430***	0.776***	0.538***
	Non-Hispanic Black	-0.017	0.163**	0.075**
	Hispanic	-0.038	0.097	0.414***
Youth				
	Children in Single-Parent Households	-0.019	-0.018	0.147***
	Below 18 Years of Age	-0.198	-0.970***	-0.990***
Rural-Urban				
	Rural	0.021	-0.016	0.008
Insurance				
	Uninsured	-0.697**	-1.953***	-0.655***
Access to Care				
	Primary Care Physicians	0.024**	0.047***	0.066***
	Mental Health Providers	0.004	0.009	0.001
Community				
	Violent Crime	0.000	-0.005	-0.004
	Injury Death	0.000	0.040	0.009

	Social Associations	0.149	-0.035	-0.064
Residential Segregation				
	Residential Segregation Non-White/White	0.046	0.037	0.086***
Employment				
	Unemployment	0.537	-0.361	0.879***
Education				
	Some College	0.049	0.002	0.207***
Economic				
	Children in Poverty	-0.050	-0.042	-0.015
	Income Inequality	-0.884	-2.211*	-0.808*
	Median Household Income	-0.00008	0.00005	0.00022***

Indicators of Statistical Significance Key:
*: Significant at the 5% level (P= 0.05)
**: Significant at the 1% level (P=0.01)
***: Highly significant (P=0.001)

We rounded median household income to the 5th digit value to create realistic and accurate interpretations of financial data. For complete regression results refer to Appendix B.

Time 1 marks the initial phases of the COVID-19 vaccination distribution period. The results in Time 1 show a statistically significant association among uninsurance rates, the prevalence of primary care providers, and the proportion of American Indian and Alaska Native individuals on COVID-19 vaccination rates (Figure 5). The statistically significant associations in Time 1 are significant across all three time periods. In Time 1, an increase in uninsurance rates was associated with decreased vaccination coverage. Alternatively, an increase in the number of

PCPs and the percentage of American Indian and Alaska Native populations were each associated with increased COVID-19 vaccination coverage.

Time 2 captures COVID-19 vaccination rates one month after the FDA approved the first COVID-19 vaccine. In Time 2, results show statistically significant associations among the following factors on COVID-19 vaccination rates: the percentage of females; the proportion of Asian, American Indian and Alaska Native, and non-Hispanic Black individuals; the percentage of individuals below 18 years of age; the prevalence of primary care physicians per 100,000 population; and uninsurance and income inequality (Figure 5). An increase in the percentage of females was associated with increased COVID-19 vaccination coverage. This association may be due to gender differences in health-related behavior. An increase in the prevalence of minority populations (including Asian, American Indian & Alaska Native, and non-Hispanic Black populations) was associated with increased COVID-19 vaccination coverage. Moreover, an increase in the number of primary care physicians per 100,000 population was associated with COVID-19 vaccination uptake. Alternatively, an increase in income inequality, uninsurance rates, and the population below age 18 was associated with decreased vaccination coverage. Income inequality influences health outcomes and lower-income individuals are more likely to be in poor health. [62] Areas with higher income inequality may report disparities in COVID-19 vaccination uptake across different socioeconomic groups.

The regression model in Time 3 yielded the highest number of statistically significant associations. Time 3 captured COVID-19 vaccination rates during the final stages of vaccine distribution and therefore, reflects increased levels of vaccination coverage. In Time 3, an increase in the prevalence of Hispanic, American Indian & Alaska Native, non-Hispanic Black populations is associated with increased COVID-19 vaccination coverage. Moreover, an increase in education and median household income was positively associated with vaccination coverage. As education and income greatly influence health outcomes, it follows that an increase in both education and median household income is associated with COVID-19 vaccination uptake. Alternatively, Time 3 indicates that an increase in unemployment, the percentage of children living in single-parent households, and residential segregation is associated with COVID-19 vaccination uptake. These findings may be investigated further. We estimate that the association of unemployment, children living in single-parent households, and residential segregation with vaccination uptake, might be influenced by targeted intervention strategies that focus on populations that encounter barriers to accessing and receiving the COVID-19 vaccine. Additionally, the results in Time 3 show negative associations among uninsurance, the proportion of the population below age 18, and income inequality, on COVID-19 vaccination rates.

The complete results of the three regression models, Time 1, 2, and 3, are included in Appendix B.

Time 1: The Initial COVID-19 Vaccine Rollout

To examine population demographics and COVID-19 vaccination, we utilize data from the 2019 Census Bureau on racial demographics across U.S. counties. In Time 1, a one-point increase in the percent of American Indian and Alaska Natives is associated with nearly a half ($\beta=0.430$, 0.430%) point increase in COVID-19 vaccination coverage. This association between COVID-19 vaccination coverage and the population percentage of American Indian and Alaska Natives is highly significant ($P=0.00$). Results indicate that the average percentage of American Indian and Alaska Natives alone among U.S. counties was 2.38% (2.384) in 2019. To date, the 2021 Census indicates that 1.3% of the American population is American Indian and Alaska Native alone. Therefore, a one-point increase in the percentage of American Indian and Alaska Natives at the county level is significant given the current racial composition.

In Time 1, a one percentage point increase in the proportion of the population under age 65 without health insurance among U.S. counties was associated with a 0.70% (β=-0.697, -0.697%) decrease in COVID-19 vaccination coverage. This association between COVID-19 vaccination coverage and the percentage of those under age 65 living without health insurance is statistically significant (P=0.004). The researchers utilize county-level uninsurance rates sourced from the 2018 Small Area Health Insurance Estimates which define uninsured as a person under age 65 who is currently not covered by insurance through a current or former employer or union, Medicare, Medicaid, Medical Assistance, purchased from an insurance company, or any other kind of government-assistance for healthcare coverage. This data features an average nationwide county-level uninsurance rate of 11.49% (11.499%). In other words, the data indicates that on average more than 1 out of every 10 county residents lack health insurance. Therefore, even a single percentage point increase in the uninsurance rate is highly significant within the population.

In Time 1, one additional primary care physician per 100,000 population results in a slight increase (β=0.024, 0.024%) in COVID-19 vaccination prevalence. The researchers utilize data from the 2018 Area Health Resource File and American Medical Association on the number of primary care providers per 100,000 population at the county level to examine indicators of healthcare access. The data reflects an average of 54 physicians per 100,000 population. Therefore, even just one additional physician per 100,000 individuals is significant in many areas. The findings indicate that an additional five physicians per 100,000 population results in a 0.12%

increase in overall vaccination coverage. The association between the proportion of primary care physicians and COVID-19 vaccination uptake is highly statistically significant (P=0.003). Refer to Appendix B for the complete regression results (i.e. measure of significance, 95% confidence intervals) in Time 1.

Time 2: The FDA Approval of the First COVID-19 Vaccine

The female variable utilized for this analysis comes from the 2019 Census Population Estimates and includes the percent of the population whose biological sex at birth is female. The data reveals that almost half (49.88%) of the population is biologically female in U.S. counties. In Time 2, a one-point increase in the proportion of county residents who are biologically female results in a 0.74% (β=0.745) increase in COVID-19 vaccination coverage. While a one percent increase in the county-level prevalence of females is significant given the current population demographics, a five percent increase (i.e. the population shifts from 49.00% to 54.00% female) in the female population is associated with a 3.73% increase in COVID-19 vaccination coverage.

In Time 2, an increase in the population of Asian, American Indian and Alaska Native, and non-Hispanic Black residents is associated with increased COVID-19 vaccination coverage. One additional increase in the percentage of Asian individuals is associated with a 0.48% (β=0.483) increase in COVID-19 vaccination coverage. This association is highly statistically significant (P=0.003). Moreover, in Time 2 one additional increase in the county-level prevalence of American Indian and Alaska Native individuals is associated with a 0.78% (β=0.776) increase in COVID-19 vaccination coverage. This association is highly statistically significant (P=0.00). Additionally, in Time 2 one additional increase in the prevalence of non-Hispanic Blacks is associated with a 0.16% (β=0.163) increase in vaccination coverage. This association is statistically significant (P=0.021).

In Time 2, a one-point increase in uninsurance (i.e., the percent of the population under age 65 living without health insurance) is associated with an astounding 1.95% (β= -1.953) decrease in COVID-19 vaccination coverage. This association between uninsurance rates and COVID-19 vaccination coverage is highly statistically significant (P=0.00). We utilize data from the 2019 U.S. Census estimates to conclude that the average U.S. county has a population of about 104,468 individuals. Therefore, a 1.95% decrease in COVID-19 vaccination rates describes an influx of nearly 2,040 individuals who were previously unvaccinated.

In Time 2, one additional primary care physician per 100,000 population is associated with a 0.04% (β=0.047) increase in COVID-19 vaccination coverage. The quantitative analysis indicates that the average U.S. county has 54 primary care providers per 100,000 population. Given the limited number of primary care providers, any additional loss or gain of a PCP is significant.

Income inequality harms health by increasing the prevalence of poverty, generating chronic stress due to increased social comparisons, diminishing societal cohesion, and destabilizing institutions that protect health. [63] We employ data sourced from the American Community Survey Estimates from 2015 to 2019 that defines income inequality as "the ratio of household income at the 80th percentile to that at the 20th percentile. For example, when the incomes of all households in a county are listed from highest to lowest, the 80th percentile is the level of income at which only 20% of households have higher incomes, and the 20th percentile is the level of income at which only 20% of households have lower incomes." [64] The data reveals that the average income inequality ratio among counties is 4.51; this means that there are over four times as many households at the 80th percentile compared to the 20th percentile. The regression analysis indicates that a one-point increase in income inequality (i.e., a county experiences an increase in income inequality causing the ratio of inequality to increase from 4.61 to 5.61) results in a 2.21 (β=-2.211) decrease in COVID-19 vaccination coverage. For example, imagine that County X has a population of 52,800 residents. County X contains a large working-class population and experienced a one-point increase in the measure of income inequality due to the closure and loss of construction-related jobs during the pandemic. According to the data, a one-unit increase in income inequality for County X would directly impact nearly 1,165 households. Refer to Appendix B for the complete regression results (i.e. measure of significance, 95% confidence intervals) in Time 2.

Time 3: The COVID-19 Vaccine Is Available for Most

Time 3 captures the final stages of the COVID-19 vaccination distribution process within the United States. The regression model in Time 3 contains the most statistically significant associations as compared to the other two models.

In Time 3, a one-point increase in the proportion of county residents who are biologically female is associated with a 0.40% (β=0.40) increase in COVID-19 vaccination coverage. This association between the prevalence of biological females and COVID-19 vaccination coverage is highly significant (P=0.011). The analysis further reveals that the average county population includes the following racial demographic composition: Hispanic (9.78%), American Indian and Alaska Native (2.38%), and non-Hispanic Black (9.01%). In Time 3, an increase in the prevalence of Hispanic, American Indian and Alaska Native, and non-Hispanic Black residents, all positively influence COVID-19 vaccination coverage. Specifically, a one percent increase in the population of Hispanics is significantly (P=0.00) associated with a 0.42% (β=0.414) increase in COVID-19 vaccination prevalence; a one-point increase in the proportion of Native Indian and Alaska Native individuals is significantly (P=0.00) associated with a 0.538% (β=0.538) increase in vaccination coverage; and a one-unit increase in the prevalence of non-Hispanic Black individuals is strongly (P=0.026) associated with a slight increase, 0.07% (β=0.075), in COVID-19 vaccination coverage. While the population of Hispanic, American Indian and Alaska Native, and non-Hispanic Black groups positively influence vaccination uptake, the association is minor as each demographic is associated with less than a one percent increase in vaccination coverage. We hypothesize that the association between minority populations on COVID-19 vaccine coverage might stem from community-based structures and systems that encourage healthy behaviors.

In the regression models, we examine the relationship between the prevalence of children living in single-parent households and COVID-19 vaccination coverage. We utilize data sourced from the 2015 to 2019 American Community Survey, which defines children living in single-parent households as the percentage of children (less than 18 years of age) living in family households that are headed by a single parent. The analysis revealed that on average, 21.92% of children live in a household headed by a single parent among U.S. counties. In Time 3, the results show that a one-point increase in the percentage of children living in single-parent households is associated with a 0.15% increase in COVID-19 vaccination coverage. This association is highly statistically significant (P=0.00). The data stipulates that if County X experiences a 5% increase in the prevalence of children living in single-parent households, it may subsequently report a

0.75% increase in COVID-19 vaccination rates. We hypothesize that perhaps this association may be influenced by several different scenarios such as: single parents may encourage their children to receive a COVID-19 vaccine if they are unable to miss work due to illness; or perhaps single parents recognize that if their child becomes sick, they are fully responsible for taking care of them. This association may be further explored in future research.

The findings in Time 3 include some of the following negative associations: a one-point increase in the percentage of the population below 18 years of age is highly ($P=0.00$) associated with a slight decrease (-0.99%, $\beta = -0.990$) in COVID-19 vaccination coverage; a one-point increase in the percent uninsured is significantly ($P=0.00$) associated with a 0.65% ($\beta= - 0.655$) decrease in COVID-19 vaccination coverage; and a one-point increase in income inequality is significantly ($P=0.03$) associated with a 0.81% ($\beta= -0.808$) decrease in vaccination prevalence. The results show that an increase in the population below 18 years of age is negatively associated with vaccination coverage. This association may be explained by several different scenarios such as, parental consent is required for individuals less than 18 years of age to receive the COVID-19 vaccine and some parents may refuse consent, many young children are dependent on their parent or legal guardian to create vaccine appointments and provide transportation to and from the vaccination site, and several other circumstances. Additionally, the results in Time 3 indicate that an increase in income inequality is associated with decreased vaccination coverage. Income inequality measures the extent to which income is evenly distributed within a population. The association between income inequality and COVID-19 vaccination rates is due to a variety of factors that should be explored in future research. For example, perhaps increased income inequality provides better access to the vaccine in wealthier as compared to low-income areas, and therefore, decreases overall vaccination coverage.

Alternatively, Time 3 includes some of the following positive associations: one additional primary care provider (PCP) per 100,000 population is significantly (P=0.00) associated with a 0.06% (β= 0.065) increase in COVID-19 vaccination rates; one unit increase in the index of non-White/White residential segregation is significantly (P=0.00) associated with a 0.09% (β= 0.086) increase in vaccination rates; a one-point increase in unemployment is significantly (P=0.00) associated with a 0.88% (β= 0.879) increase in COVID-19 vaccination coverage; a one-point increase in the percentage of individuals that received some college education is significantly (P=0.00) associated with a 0.21% (β= 0.207) increase in vaccination coverage; and a one unit increase in median household income is associated with a slight (β=0.0002203) increase in vaccination coverage.

In Time 3, an increase in the prevalence of PCPs is associated with COVID-19 vaccination uptake. The results suggest that if the average county gained five additional PCPs per 100,000 population, it may experience an influx of nearly 34,470 vaccinated individuals (based on the average county population of about 104,468 total people). Increasing the number of primary care providers within a county can positively contribute to vaccination uptake by providing more opportunities for residents to receive a COVID-19 vaccine. For example, an additional primary care physician in a rural community may allow someone to receive a COVID-19 vaccine who was previously unable to due to geographic barriers and a lack of vaccine sites. Additionally, in Time 3 an increase in residential segregation between White and non-White populations was associated with an increase in vaccination coverage. We hypothesize an increase in segregation might encourage minority populations to become more concentrated within their own communities, which may foster the exchange of COVID-19-related information and encourage vaccination uptake through a community-minded approach that protects the well-being of its members. In Time 3, an increase in unemployment is significantly associated with COVID-19 vaccination uptake. This association should be further examined in future research. We hypothesize that perhaps the association between unemployment and COVID-19 vaccination uptake might be explained by scenarios such as, unemployed individuals may have more free time to receive the vaccine, or unemployed individuals might receive the vaccine to become eligible for certain jobs. Additionally, the Time 3 findings show that an increase in median household income is associated with COVID-19 vaccination uptake. The results indicate that if the average county population experienced a $1,000 increase in median household income, it may result in an astounding influx of nearly 22,980 previously unvaccinated residents. Refer to Appendix B for the complete regression results (i.e. measure of significance, 95% confidence intervals) in Time 3.

Discussion

The research questions RQ1 and RQ2 aim to examine the association of key healthcare access indicators and socioeconomic factors on COVID-19 vaccination rates among U.S. counties. The regression models in Time 1, Time 2, and Time 3 found statistically significant associations among uninsurance rates, the prevalence of primary care providers (PCPs), and the population of certain minority groups on COVID-19 vaccination rates. The findings suggest that an increase in uninsurance among U.S. counties is associated with lower vaccination coverage. Public health agendas that aim to increase COVID-19 vaccination rates across the U.S. should consider initiatives that combat barriers to health insurance and assist the uninsured in obtaining coverage. Moreover, the findings also suggest that an increase in the number of primary care providers per 100,000 population is significantly associated with COVID-19 vaccination uptake. The ratio of PCPs per county population serves as a critical indicator of healthcare access. Policymakers interested in public health and the ongoing COVID-19 pandemic should advocate for the importance of PCPs in facilitating vaccination uptake.

Another notable association across the three regression models indicates a statistically significant association between COVID-19 vaccination and the population of Native Indian and Alaska Native individuals. The results suggest that an increase in minority populations is associated with COVID-19 vaccination uptake. We hypothesize that this association might be rooted in targeted intervention strategies that focus on providing equitable access to COVID-19 vaccines for minority groups. Policymakers should interpret this finding as a positive opportunity to further develop vaccination distribution strategies that reach all segments of the population. However, the association between race and ethnicity on COVID-19 vaccination coverage among U.S. counties should be further explored in future research.

Previous research indicates vaccination disparities between rural and urban counties on COVID-19 vaccination coverage. The third research question, RQ3, examines the rural-urban continuum across the United States. While relevant research suggests that rural areas experience lower COVID-19 vaccination rates as compared to urban geographics, our three-pronged linear regression analysis did not yield statistically significant associations between rurality and urbanicity and COVID-19 vaccination rates. The association of COVID-19 vaccination rates with metro and non-metro geographies may be examined in future research.

Limitations

We identified two key limitations of this research. In this study, we utilized a cross-sectional approach to capture data on specific dates and points in time. However, a key limitation of this approach is that we were only able to examine the association between two variables and were unable to infer causality. Another limitation of this study relates to missing variables and observations. To create accurate findings, we excluded all variables with less than 2,500 observations and there are 3,142 total counties and county-equivalents in the U.S. Therefore, potentially influential associations were excluded from the analysis because they failed to represent a comprehensive majority of counties. Some variables that were excluded from the analysis include indicators of severe housing issues, the rate of chronic diseases such as obesity and diabetes, and seasonal influenza vaccine rates. Future research should continue to collect data at the county level to provide more understanding of a diverse array of factors.

Concluding Remarks

This research further illuminates the association among key indicators of healthcare access, socioeconomic factors, and population demographics on COVID-19 vaccination rates among U.S. counties. The most notable associations reinforce the importance of healthcare access and regular interaction with the healthcare system in a time of COVID-19. Moreover, the results showcase the importance of health insurance coverage on long-term health outcomes and health behaviors.

Appendix A

Data Dictionary: Details on the variables utilized for analysis

The measure of COVID-19 vaccination prevalence is sourced from the CDC COVID-19 Vaccination database at the U.S. county level. [65]

COVID-19 Vaccination

Variable	Description	Time Period(s)
Vaccination Completeness	The percent of people who have completed a primary series (received a second dose have a two-dose vaccine or one dose of a single-dose vaccine) based on the jurisdiction and county where the vaccine recipient lives. The CDC dataset is a nationally representative dataset that represents vaccine partners including, "jurisdictional partner clinics, retail pharmacies, long-term care facilities, dialysis centers, Federal Emergency Management Agency and Health Resources and Services Administration partner sites, and federal entity facilities." [66] This dataset is updated on a regular basis and reflects daily vaccination information across U.S. counties.	Since May 24, 2021, this dataset has been updated on a regular basis with daily COVID-19 vaccination data.

The following measures are sourced from the 2021 County Health Rankings and Roadmaps dataset. [67]

A. Population demographics in the U.S.

Variable	Description	Data Source	Year
Female	The percent of the population that is biologically female.	Census Population Estimates	2019

Hispanic	The percent of the population that is Hispanic alone.	Census Population Estimates	2019
Asian	The percent of the population that is Asian alone.	Census Population Estimates	2019
American Indian & Alaska Native	The percent of the population that is American Indian and Alaska Native alone.	Census Population Estimates	2019
Non-Hispanic Black	The percent of the population that is Black or African American alone.	Census Population Estimates	2019
Adolescence (Below 18 years of age)	The percentage of the population that is less than 18 years of age.	Census Population Estimates	2019

B. Examining the rural-urban continuum

Variable	**Description**	**Data Source**	**Year**
Rural	The prevalence of counties with a population of less than 50,000 people. Specifically, the U.S. Census Bureau defines rural as any population, housing, or territory not in an urban area. [68] The Census Bureau defines rural as any population, housing, or territory that is not in an urban area. Urban areas consist of either: 1) urbanized areas (UAs) of 50,000 people or more; or 2) urban clusters (UCs) of at least 2,500 and less than 50,000 people.[69]	Census Population Estimates	2010

C. Variables measuring key indicators of healthcare access

Variable	Description	Data Source	Year
Primary Care Physicians	The number of primary care physicians per 100,000 county residents.	Area Health Resource File / American Medical Association	2018
Mental Health Providers	The number of mental health providers per 100,000 county residents. In this analysis, mental health providers are defined as psychiatrists, psychologists, licensed clinical social workers, counselors, marriage and family therapists, professionals that treat alcohol and other drug abuse, and advanced practice nurses specializing in mental healthcare.[70]	CMS, National Provider Identification	2020
Uninsured	The percentage of the population under age 65 without health insurance. A person is uninsured if they are currently not covered by insurance through a current/former employer or union, purchased from an insurance company, Medicare, Medicaid, Medical Assistance, any kind of government-assistance plan for those with low incomes or disability, TRICARE or other military health care, Indian Health Services, VA, or any other health insurance or health coverage plan. [71]	Small Area Health Insurance Estimates	2018

D. Social and economic variables that influence long-term health outcomes

Variable	Description	Data Source	Year
Crime & injury-related deaths			
Violent Crime	The number of reported violent crime offenses per 100,000 population. Violent crime is the number of violent crimes reported per 100,000 population. Violent crimes include murder, manslaughter, kidnapping, aggravated assault, forcible sex offenses, robbery, arson, extortion, extortionate extension of credit, and burglary of a dwelling. [72] This variable includes crimes counted in the police precinct where they occur. This measure only includes the crimes reported to the police that are then reported to the FBI. [73]	Uniform Crime Reporting - FBI	2014 & 2016
Injury Deaths	The number of reported injury deaths per 100,000 population. This measure, injury death, is the number of deaths from planned (e.g. homicide or suicide) and unplanned (e.g. motor vehicle deaths) injuries per 100,000 population. This measure includes injuries from all causes and intents. [74]	National Center for Health Statistics - Mortality files	2015-2019
Children in poverty and/or living in single-parent households			
Children in Single-Parent Households	The total percentage of children that live in a household headed by a single parent. This measure includes the percentage of the population under age 18 living in family households headed by a single parent. [75]	American Community Survey, 5-year estimates	2015-2019
Children in poverty	The percentage of the population that is less than 18 years of age and living in poverty. In this measure, poverty is defined by the family unit. Therefore, either everyone in the family is in poverty or no one in the family is in	Small Area Income and Poverty Estimates	2019

	poverty. The characteristics used to determine whether or not a family qualifies as poor include: the number of people in a family unit, the number of related children less than 18 years of age, and whether or not the primary householder is over age 65. [76]		
Membership and social associations			
Social Associations	The number of membership associations per 10,000 population. Social associations include involvement in membership organizations such as civic organizations, labor organizations, business organizations, and professional organizations. [77]	County Business Patterns	2018
Non-White/White residential segregation			
Residential Segregation Non-White / White	An index of dissimilarity where higher values indicate greater residential segregation between non-White to White county residents. The residential segregation index ranges from 0 (complete integration) to 100 (complete segregation). The index score can be interpreted as the percentage of either non-White or White residents that would have to move to different geographic areas to produce a distribution that matches that of the larger area. [78]	American Community Survey, 5-year estimates	2015-2019
Income and employment			
Income Inequality	This measure, income inequality, is the ratio of household income at the 80th percentile to that at the 20th percentile. To elaborate, if the household level incomes in a county were listed from highest to lowest, the 80th percentile is the income at which only 20% of households have higher incomes. The 20th percentile is the level of income at which 80% of households have higher incomes. [79]	American Community Survey, 5-year estimates	2015-2019

Median Household Income	This is the income at which half of the households in a county earn more and half earn less. In this analysis, income is defined as the sum of the total amounts reported for: wage or salary income; net self employment income; interest, dividends, or net rental or royalty income or income from estates and trusts; social security or Railroad Retirement income; supplemental security income (SSI); public assistance or welfare payments; retirement, survivor, or disability pensions; and all other income. [80]	Small Area Income and Poverty Estimates	2019
Unemployment	The percentage of the population 16 and up that is unemployed but seeking work. Unemployment is the percentage of the county's civilian labor force, ages 16 and older, that is unemployed but seeking work. [81]	Bureau of Labor Statistics	2019
Education			
Some college	The percentage of adults aged 25 to 44 with some post-secondary education. Post-secondary education includes enrollment in vocational and technical schools, junior colleges, and four-year colleges. This measure includes individuals who pursued education following high school but did not receive a degree as well as those who attained degrees. [82]	American Community Survey, 5-year estimates	2015-2019

Appendix B

Regression Analysis Complete Results: Insignificant and Significant Associations

Time 1 – The initial stages of vaccine rollout (vaccine available for some).

		Beta	Significance (P-Value)	95% CI Lower	95% CI Higher
Gender					
	Female	0.062	0.714	-0.275	0.399
Race					
	Hispanic	-.038	0.328	-.116508	0.040
	Asian	0.164	0.091	-0.027	0.355
	American Indian & Alaska Native	0.430	0.000	0.311	0.311
	Non-Hispanic Black	-0.017	0.722	-0.115	0.080
Youth					
	Children in Single-Parent Households	-0.019	0.549	-0.083	0.045
	Below 18 Years of Age	-0.198	0.031	-0.587	0.190
Rural-Urban					
	Rural	0.021	0.292	-0.018	0.060
Insurance					
	Uninsured	-0.697	0.004	-1.162	-0.232
Access to Care					

	Primary Care Physicians	0.024	0.003	0.009	0.040
	Mental Health Providers	0.004	0.079	0.000	0.008
Community					
	Violent Crime	0.000	0.977	-0.004	0.004
	Injury Death	0.000	0.984	-0.037	0.036
	Social Associations	0.149	0.101	-0.030	0.329
Residential Segregation					
	Residential Segregation Non-White / White	0.046	0.069	-0.004	0.095
Employment					
	Unemployment	0.537	0.176	-0.250	1.323
Education					
	Some College	0.049	0.349	-0.056	0.154
Economic					
	Children in Poverty	-0.050	0.461	-0.183	0.084
	Income Inequality	-0.884	0.055	-1.790	0.021

	Median Household Income	0.000	0.056	0.000	0.000

Time 2 – One month after the FDA approved the first COVID-19 vaccine (vaccine available for many).

		Beta	Significance (P-value)	95% CI Lower	95% CI Higher
Gender					
	Female	0.745	0.001	0.322	1.169
Race					
	Hispanic	0.097	0.232	-0.064	0.258
	Asian	0.483	0.003	0.177	0.789
	American Indian & Alaska Native	0.776	0.000	0.540	1.012
	Non-Hispanic Black	0.163	0.021	0.026	0.301
Youth					
	Children in Single-Parent Households	-0.018	0.747	-0.132	0.095
	Below 18 Years of Age	-0.970	0.002	-1.557	-0.383
Rural-Urban					
	Rural	-0.016	0.595	-0.075	0.043
Insurance					
	Uninsured	-1.953	0.000	-3.001	-0.906
Access to Care					

	Primary Care Physicians	0.047	0.001	0.019	0.075
	Mental Health Providers	0.009	0.066	-0.001	0.018
Community					
	Violent Crime	-0.005	0.103	-0.011	0.001
	Injury Death	0.040	0.182	-0.019	0.099
	Social Associations	-0.035	0.778	-0.284	0.213
Residential Segregation					
	Residential Segregation Non-White / White	0.037	0.253	-0.028	0.102
Employment					
	Unemployment	-0.361	0.535	-1.522	0.800
Education					
	Some College	0.002	0.983	-0.166	0.170
Economic					
	Children in Poverty	-0.042	0.675	-0.242	0.158
	Income Inequality	-2.211	0.029	-4.188	-0.235
	Median Household Income	0.000	0.528	0.000	0.000

Time 3 – The final stages of vaccine rollout (vaccine available for most).

		Beta	Significance (P-value)	95% CI Lower	95% CI Higher
Gender					
	Female	0.400	0.011	0.094	0.705
Race					
	Hispanic	0.414	0.000	0.327	0.502
	Asian	0.169	0.149	-0.063	0.400
	American Indian & Alaska Native	0.538	0.000	0.386	0.689
	Non-Hispanic Black	0.075	0.026	0.009	0.142
Youth					
	Children in Single-Parent Households	0.147	0.000	0.082	0.213
	Below 18 Years of Age	-0.990	0.000	-1.289	-0.691
Rural-Urban					
	Rural	0.008	0.673	-0.028	0.043
Insurance					
	Uninsured	-0.655	0.000	-0.905	-0.405
Access to Care					

	Primary Care Physicians	0.066	0.000	0.046	0.085
	Mental Health Providers	0.001	0.543	-0.003	0.005
Community					
	Violent Crime	-0.004	0.053	-0.008	0.000
	Injury Death	0.009	0.595	-0.026	0.044
	Social Associations	-0.064	0.403	-0.218	0.089
Residential Segregation					
	Residential Segregation Non-White / White	0.086	0.001	0.039	0.134
Employment					
	Unemployment	0.879	0.002	0.330	1.428
Education					
	Some College	0.207	0.000	0.120	0.295
Economic					
	Children in Poverty	-0.015	0.783	-0.122	0.092
	Income Inequality	-0.808	0.031	-1.540	-0.075
	Median Household Income	0.000	0.000	0.000	0.000

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[81] University of Wisconsin Population Health Institute. (2023). *Unemployment*. County Health Rankings & Roadmaps. Retrieved March 18, 2023, from https://www.countyhealthrankings.org/explore-health-rankings/county-health-rankings-model/health-factors/social-economic-factors/employment/unemployment?year=2022

[82] University of Wisconsin Population Health Institute. (2023). *Some College.* County Health Rankings & Roadmaps. Retrieved March 18, 2023, from https://www.countyhealthrankings.org/explore-health-rankings/county-health-rankings-model/health-factors/social-economic-factors/education/some-college?year=2022

ACADEMIC VITA

Isabella Rater

EDUCATION

The Pennsylvania State University
The Schreyer Honors College — Class of 2023
College of Health and Human Development — Penn State Schreyer Honors Scholar
Major | Health Policy & Administration (B.S.) — Dean's Lists | All semesters: 7 consecutive
Minor | Communications Arts and Sciences

PUBLICATION & HONORS THESIS

***Publication* |** "A Multistakeholder Effort in Pennsylvania to Improve the Accuracy of Reporting Fatal Drug Overdoses," The American Journal of Accountable Care, December 2022

- Critically assisted health services research team providing research skills, quantitative analysis, and writing expertise
- Implemented more than 30 writing and structural revisions to produce peer-reviewed manuscript

***Honors Thesis* |** "The Effect of Socioeconomic Factors and Healthcare Access Indicators on COVID-19 Vaccination Rates," anticipated completion: May 2023

- Utilized statistical software to analyze two nationally representative datasets, produced significant findings and innovations
- Discovered primary drivers of COVID-19 vaccination uptake at the county level
- Developed academic writing skills, produced five notable figures and 23 pages of discussion

WORK EXPERIENCE

UNDERGRADUATE RESEARCH ASSISTANT | University Park, PA — *Aug. 2021 - present*
Health Services Research Assistant

- Execute in-depth data analysis and statistical programming
- Contribute to weekly discussions to fuel collaboration and generate innovation
- Formulate primary research including -- 8 key informant interviews and 3 focus groups with 15 PA residents

HUB COPY CENTRAL | University Park, PA — *Sept. 2019 - present*
Penn State Student Employee

- Foster a productive and positive workplace environment
- Practice excellent customer service
- Advise fellow students on printing and copying services

RESEARCH INTERNSHIP | University Park, PA — *May 2022 - Aug. 2022*
Penn State Health Services Research Intern

- Conducted multifaceted health services research
- Strategically formulated and reviewed manuscripts
- Analyzed COVID-19 vaccination rates at the county level

RESEARCH INTERNSHIP | University Park, PA *May 2021 - Aug. 2021*

Penn State Health Services Research Intern

- Bolstered critical-thinking skills to examine 67 Pennsylvania counties
- Generated and interpreted county-level data
- Practiced exceptional professional conduct with research advisors and stakeholders

RECEPTIONIST | State College, PA *Dec. 2020 - Aug. 2021*

Receptionist at Looks Hair Design

- Strategically created appointment bookings and processes
- Employed excellent interpersonal skills to assist customers

ACADEMICS, LEADERSHIP, & INVOLVEMENT

Leadership

Board Member and Peer Mentor, Health Policy Administration Peer Mentor Program | *Aug. 2022 - present*

- Serve as one of five students selected to advise and assist undergraduate peers through mentorship
- Organize, coordinate, and conduct monthly meetings among 35 members

Volunteer, Wesley Foundation at Penn State, Abba Java Coffee House volunteer | *Jan. 2019 - present*

- Helping to provide a safe interdenominational environment to support student needs
- Preparing and coordinating food donations

Board Member, Student Advisory Board on Student Poverty | *Nov. 2021 - May 2022*

- Created a student center aimed to combat food insecurity
- Collaborated with university executive administration

Scholarly Involvement

Finalist, Undergraduate Case Competition in Health Administration | *Nov. 2022*

- Earned finalist designation (top 4) out of 11 other teams
- Created strategic organizational plan to reduce hospital-acquired infections at MUSC health

The National Honor Society for Health Professionals Upsilon Phi Delta | *Apr. 2022 - present*

- Earned induction on behalf of Penn State Department of Health Policy Administration staff/faculty
- Work with 20 other scholars to engage in academic excellence

The Golden Key International Honour Society, Penn State University | *Jan. 2022 - present*

- Hold honor membership among the top 15% of Penn State 2023 graduating class to world's largest collegiate honor society

AWARDS & RECOGNITIONS

Fasola Family Honors Scholarship, College of Health & Human Development | *Fall 2022 - Spring 2023*

- Awarded for academic excellence and scholarship

Francis Hoffman Award for Excellence in Writing | *Fall 2021 - Spring 2022*

- Nominated by Penn State Health Policy Administration faculty for academic writing

Fasola Family Honors Scholarship, College of Health & Human Development | *Fall 2021 - Spring 2022*

- Awarded for academic excellence and scholarship

Keynote speaker in the Penn State Health & Human Development Research Expo | *Fall 2021*

- Represented health services research to 60 university faculty members and peers

Bugbee-Falk Book Award Recipient | *Fall 2021*

- Nominated by Penn State Health Policy Administration faculty to receive professional library